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955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B69 03079

SUBJECT: Discussion of Reentry Spacecraft Heat Shield Technology Studies at Martin-Marietta, Denver
Case - 103-8

DATE: March 21, 1969

FROM: D. E. Cassidy
C. C. Ong

ABSTRACT

According to Martin-Marietta, ablator heat shield technology for the medium to high L/D reentry spacecraft is well in hand. They are investigating a low cost ablative system incorporating a thermo-structure which could eventually be converted to a radiative heat shield system with little or no penalty to the spacecraft structure.

Columbium metal appears to have good structural properties for a reusable radiative heat shield. However, the oxidation resistant coating for columbium (or any of the refractory metals) is a major obstacle in developing a multiple reuse radiative heat shield for reentry spacecraft application.

The ASCEP and HASP are Air Force Flight Dynamics Laboratory contracted programs designed to evaluate columbium, tantalum, Haynes 25 and advanced TD nickel for spacecraft structural and radiative heat shield applications. It is anticipated that Martin will review both programs for NASA and Bellcomm in the near future.

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MEMORANDUM FOR FILE

The authors had personal discussions with representatives of the Martin-Marietta Corporation at Denver, Colorado. The Martin participants were R. Davis, D. V. Sallis, and W. F. Barrett. The discussions were directed toward material development and heat shield design for application on reusable spacecraft.

Introduction

Martin-Marietta has been developing and evaluating structural concepts, using both ablative and radiative heat shields, for application on reusable reentry spacecraft. Two of the major program applications conducted previously by Martin in support of their efforts were the PRIME (Precision Recovery Including Maneuvering Entry, SV-5) small scale reentry flight test and the ASCEP (Advanced Structural Concepts Experimental Program). Both programs were under Air Force contracts. the Prime vehicles were used to test the application of an ablative heat shield to medium hypersonic L/D (≈ 1.3) reentry from low earth orbit as well as other facets of reentry. The ASCEP program evaluated the application of coated columbium and Haynes 25 alloy to hot load carrying reentry structures. The ASCEP included a ground test apparatus that consisted of a 1/3 scale length of spacecraft (aerospace plane) body section constructed of columbium on the lower surfaces and super alloy Haynes 25 on all the upper surfaces. Twin titanium tanks filled with liquid nitrogen were inside the structure to simulate propellant tanks. The apparatus was exposed to static structural loading and heating lamps to simulate typical entry conditions from low earth orbit.

A new program, HASP (Hypersonic Aerospace Structures Program), is currently in progress at Martin to investigate TD Ni-Cr (Thoria Dispersion Strengthened Nickel - Chromium) and a new generation of tantalum alloy, Ta-222. The initial phases of the program involve physical property definition as well as structural and thermal analyses. The program will follow a similar course of experimental development as the ASCEP with the eventual fabrication of a 6 foot nose section based on the Flight Dynamic Laboratory FDL-5 spacecraft configuration. The section will be fabricated from Ta-222, columbium and Haynes 25 in appropriate areas.

Ablative Systems

In the opinion of the Martin people, the PRIME vehicles established a high degree of confidence in the use of ablator systems for a medium L/D reentry vehicle.* The subsystems inside the recovered PRIME vehicle (only one was successfully air snatched) were operational and could have reflown. The ablator system, as anticipated, could not be reused and would require replacement.

The cost of reusing such a vehicle (and a large manned vehicle as well) depends to a great extent on the heat protection system. To reduce the replacement cost for future applications, Martin is currently evaluating the possibility of reducing the cost of ablator fabrication. As one example, the elastomeric ablator material on the PRIME was hand filled into a honeycomb matrix, which was attached to the load bearing structure, in a manner similar to the technique used on Gemini and Apollo. The honeycomb is required to add structural integrity to the ablator in the pyrolysis zone where the material density and strength becomes very low as well as to provide a bonding to the substructure. By using an alternate method of ablator reinforcement or possibly even eliminating the reinforcement, the time to fabricate an ablator panel could be substantially reduced. In addition, methods of reducing the man hours required for attaching and detaching the ablator panels to the main structure are also under study.

Radiative Systems

The ASCEP is considered by the Martin people to have been a very useful tool for understanding and evaluating the radiative heat shield application to large hot load carrying structures. They believe the redundant structure concepts employed on the ASCEP are feasible for application to high L/D spacecraft. The question of the multiple reuse of coated columbium panels, however, was left unanswered. The major problem area is the oxidation resistant coatings required on refractory metals. In general, the ASCEP could not demonstrate multiple reuse of coated panels due to coating failures. Out of the

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*Of course the Mercury, Gemini, Apollo and other reentry systems contributed to this confidence in ablator systems application as well.

30 columbium honeycomb panels (38" x 14 5/8" x 7/16" was the largest panel) that made up the lower surface heat shield, only a few panels could be recycled through the simulated entry loading and heating, and only one panel was used through 10 cycles.

It is imperative that a reliable high temperature coating be developed if columbium (or any refractory metal) is to be used on a low cost reusable spacecraft. It appears from talking to the Martin people, however, that there is only a relatively small effort presently being expended in coating development. Although a refractory metal heat shield is not the only reusable concept (non-metalic radiators* or film cooled surfaces could be other possibilities), the refractory metals do have very desirable high temperature properties if protected from oxidation. Coated columbium has multiple reuse potential at temperatures up to 2500°F, which could constitute most of the lower surface of a reusable spacecraft depending on its configuration and operational mission.

In the HASP program, the same problem of coatings for the tantalum alloy Ta-222 is present; in fact, due to the higher temperatures, the problem is more severe for the tantalum coatings. The Ta-222 can retain considerable structural strength up to 3600°F, but it is not believed that coatings could be made available for such high temperature applications. The potential application of tantalum, therefore, is restricted to 3000°F for thin sheets and 3200°F for sheets greater than 12 mil. With a 3000°F to 3200°F temperature limit instead of the 2500°F for columbium, the spacecraft configuration and operational mission could be made more flexible. Considerably more material property definition will be required for tantalum application. The conclusions from the HASP program on tantalum coatings (assuming better coatings are developed during the HASP) should also be applicable to columbium coatings.

The new generation of TD Ni-Cr has potential application to 2200°F without the need of oxidation resistant coatings. To date, test results show that TD Ni-Cr sheet (.010 to .012 inches thick) can survive 12 two hour heating cycles with a peak temperature of 2000°F. The HASP program is intended to better define the design allowables for TD Ni-Cr.

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*Lockheed is developing LI-1500, a silica material. Trip Report - Discuss Stage and One-Half Launch System Studies at Lockheed, Bellcomm Memo for File, D. E. Cassidy and C. C. Ong, February 4, 1969.

Comments

Although it is anticipated that some type of reusable heat shield will eventually be developed, an ablator system (preferably low cost) might be required in the interim. It would be desirable if a spacecraft could be designed to use an ablative system initially and allow for a reusable heat shield retrofit. Martin personnel feel this is quite reasonable when the double wall construction is employed. The double wall consists of a load carrying substructure and separate heat shield mounted on the substructure. Martin is analyzing systems which would use a low density (15 lbs/ft^3) elastomeric ablator initially and then be converted to columbium. They feel that little or no penalty would be imposed on the basic structure of the vehicle using this approach.

Since the data generated in the ASCEP and HASP programs have significant bearing on the question of being able to develop multiple reusable heat shields for a new low cost earth orbital transportation system, the authors have invited the Martin representatives to present a more thorough review of both programs for interested NASA and Bellcomm personnel. Interested persons should contact the authors.

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